New Experimental Wind Tunnel Research Capabilities at UAH for Investigation of Shock-Wave-Boundary-Layer-Interactions

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Propulsion Research Center

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

9th Annual Shock Wave/Boundary Layer Interaction (SWBLI) Technical Interchange Meeting

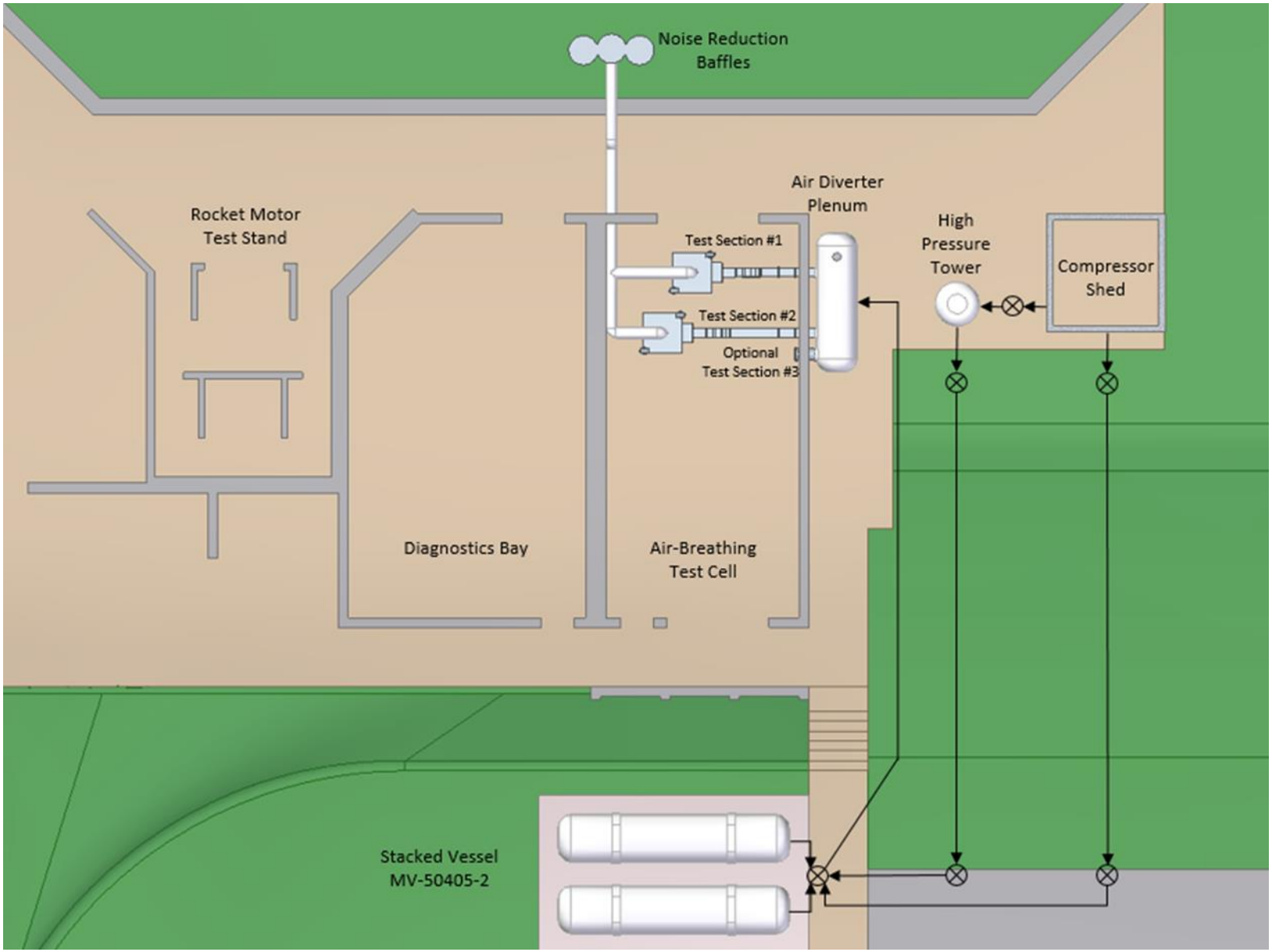
May 24-25, 2016, Cleveland Ohio

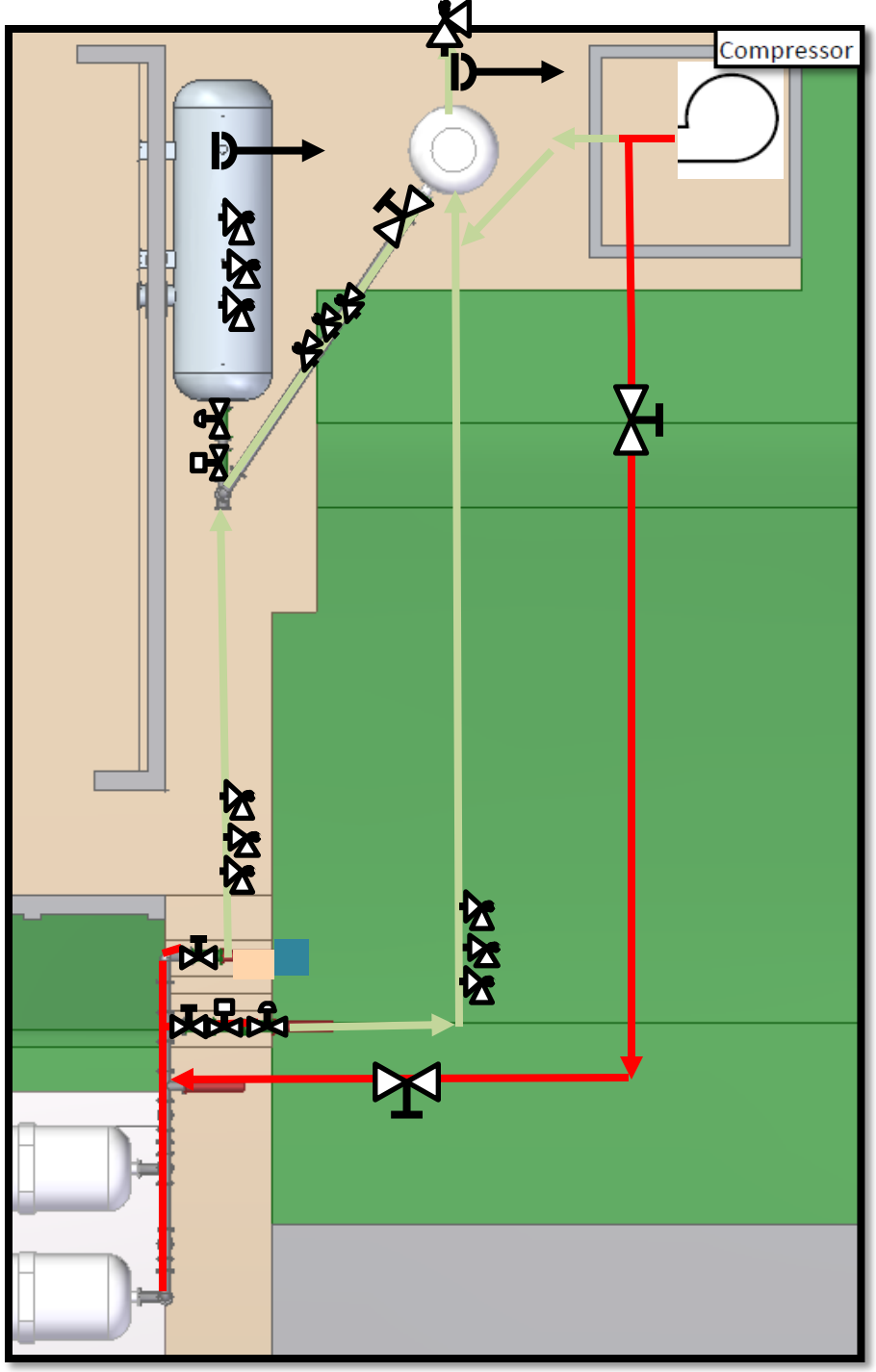
JOINT Numerical and Experimental EFFORTS AND COOPERATION ARE VERY IMPORTANT

Propulsion Research Center

Increased collaboration between computational and experimental work to improve our understanding and insight into FLOW PHYSICS and CONTROL.

Overall SS/TS/WT Arrangement





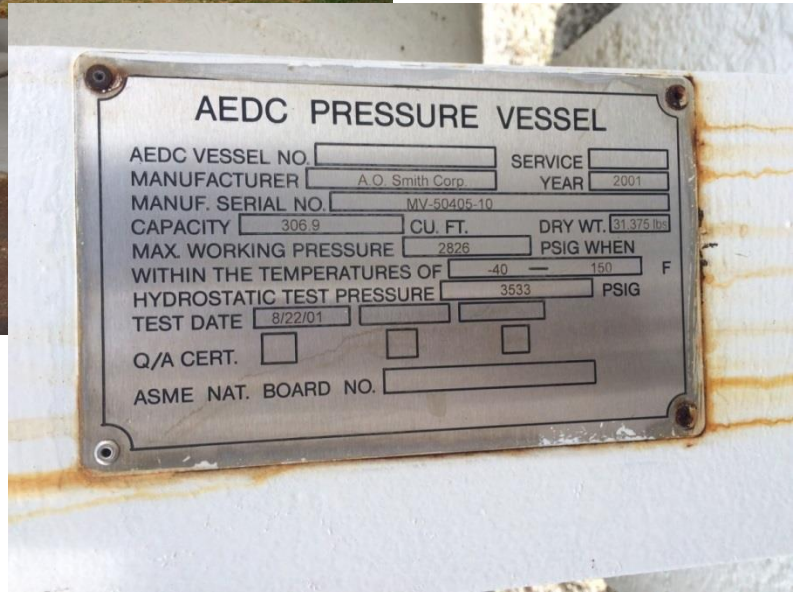
SS/TS/WT
Pipe Connections

2500 psi line 3”

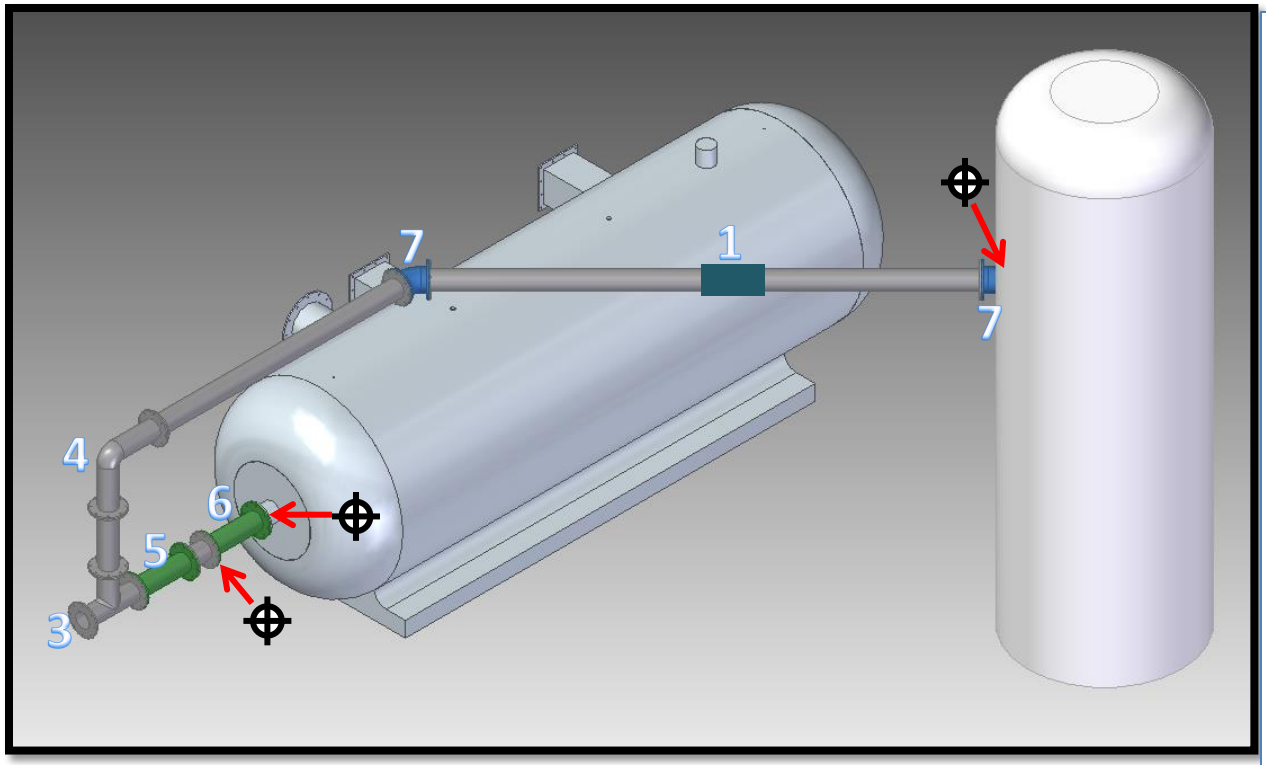
300 psi
line 3” & line 6”

- Manual Gate Valve
- Pneumatic Valve
- PR Control Vavle
- Undeclared Vavle
- Burst Disk
- Relief Vavle

DONATED HIGH PRESSURE AIR STORAGE TANKS: A NEW ADDITION TO THE UAH - PRC



Valve Identification



Key:

1: 6” 300psi Manual Gate Valves

3: 6” LP Tee with CAPPED OPENING

4: 6” 90 Degree Bend

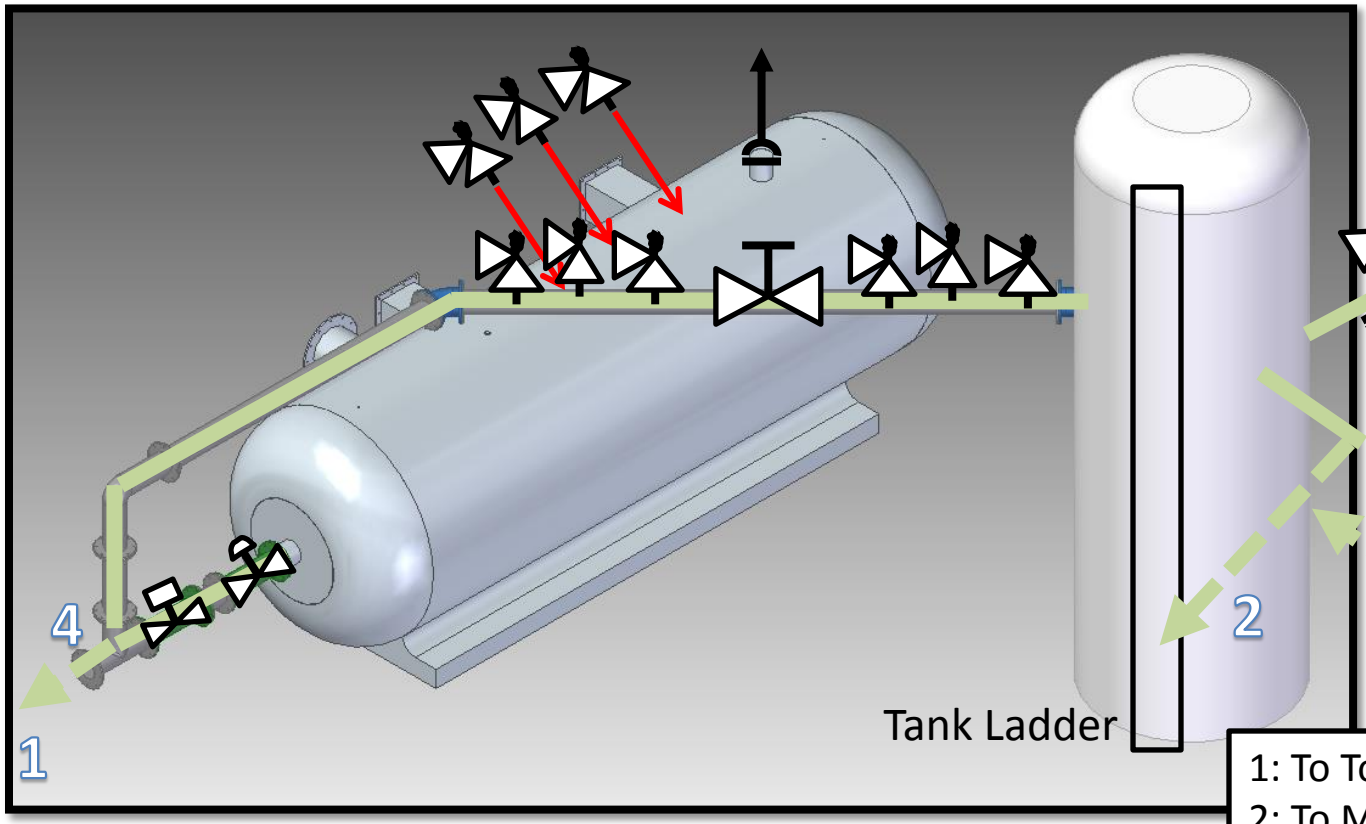
5: 6” 300psi Pneumatic Valve

6: 6” 300 psi PR Control Valve

7: 6” 45 Degree Bend

⌖: Pressure tap - ”T” Connection for Both Analog and Digital Pressure Gauges.

Valve Identification



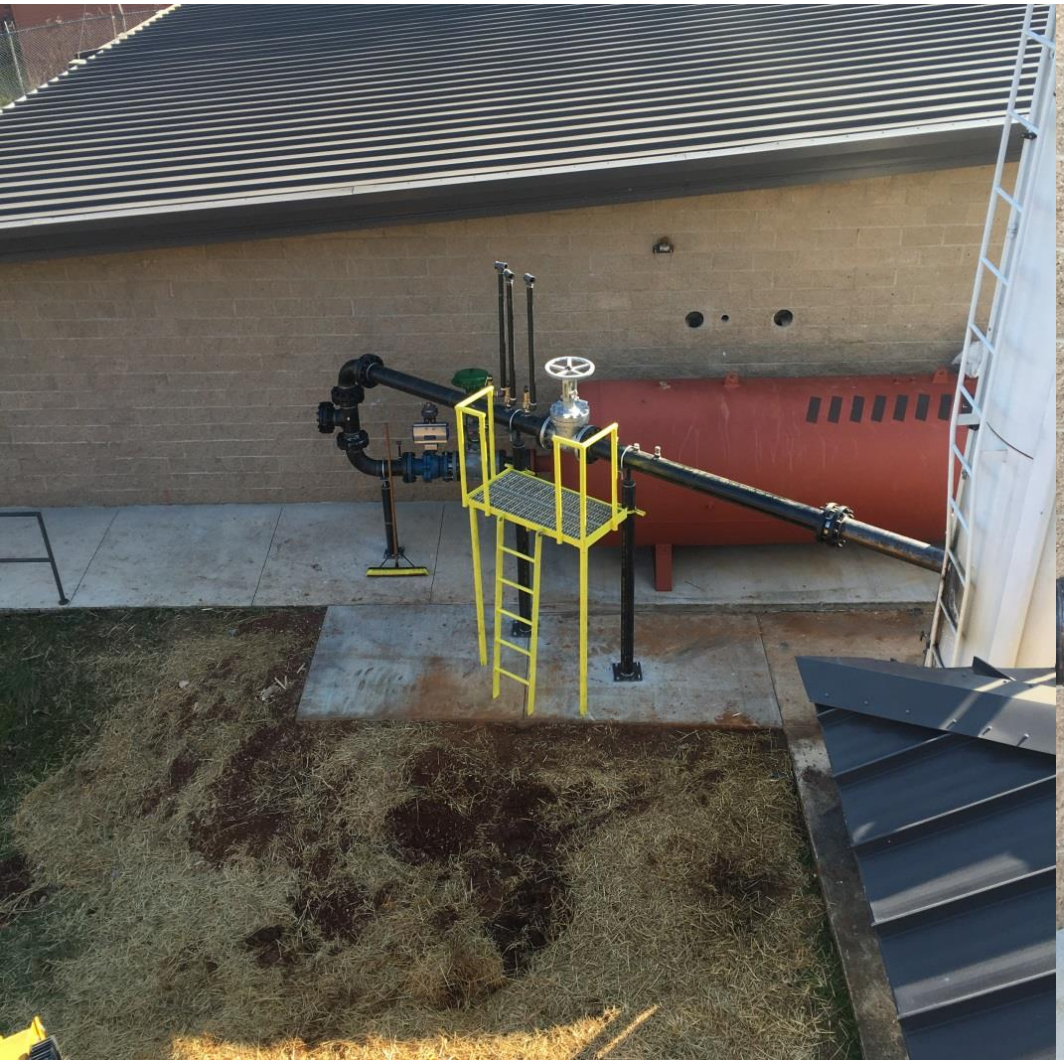
Key:

- Manual Gate Valve
- Pneumatic Valve
- PR Control Vavle
- Undeclared Vavle
- Burst Disk
- Relief Vavle

300 psi line 6”

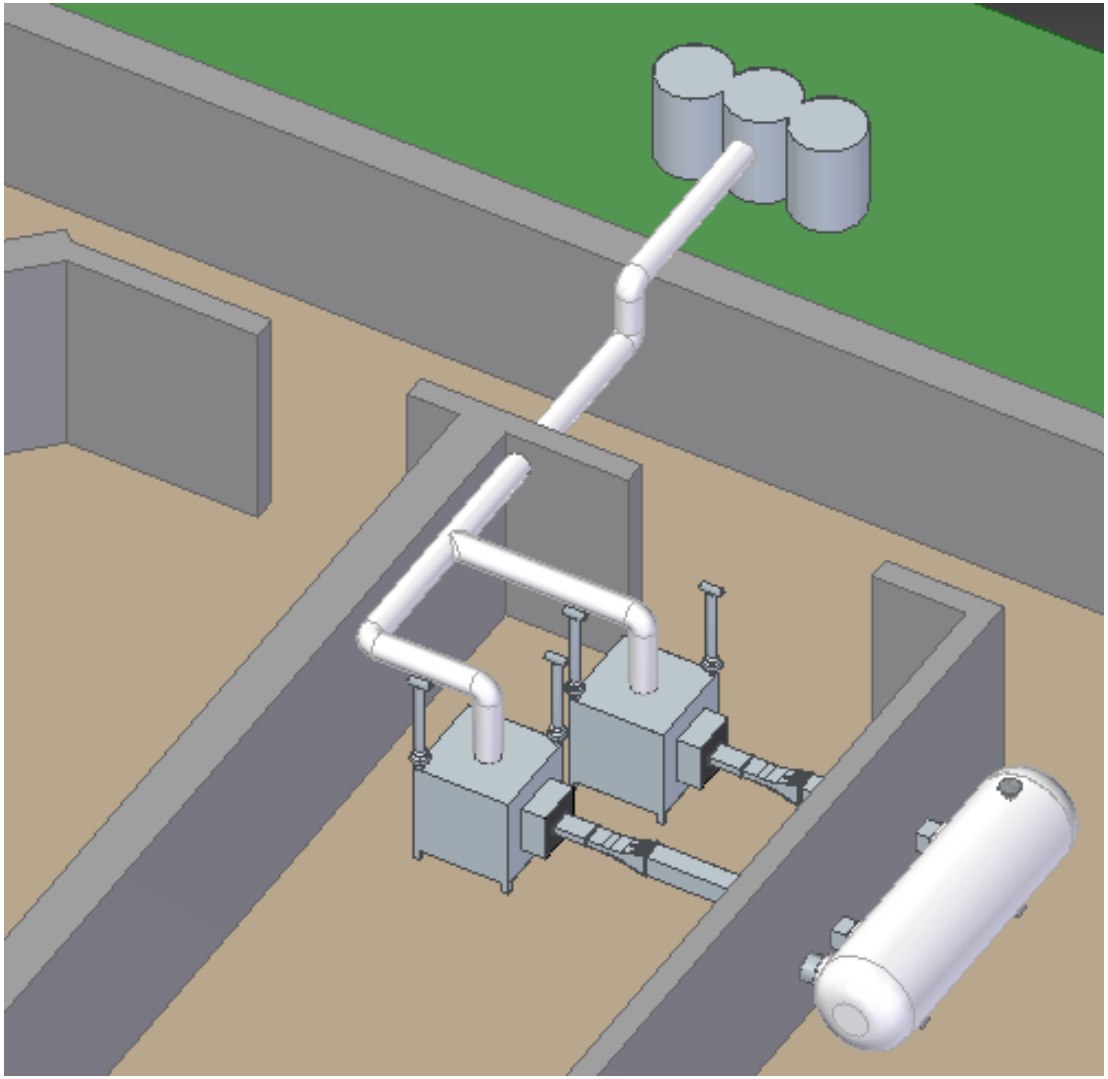
1: To Top Line HP Tank Farm
2: To Middle Line HP Tank Farm
3: From Compressor Shed
4: 6” LP Tee with CAPPED OPENING

SuperSonic/TransSonic/WindTunnel

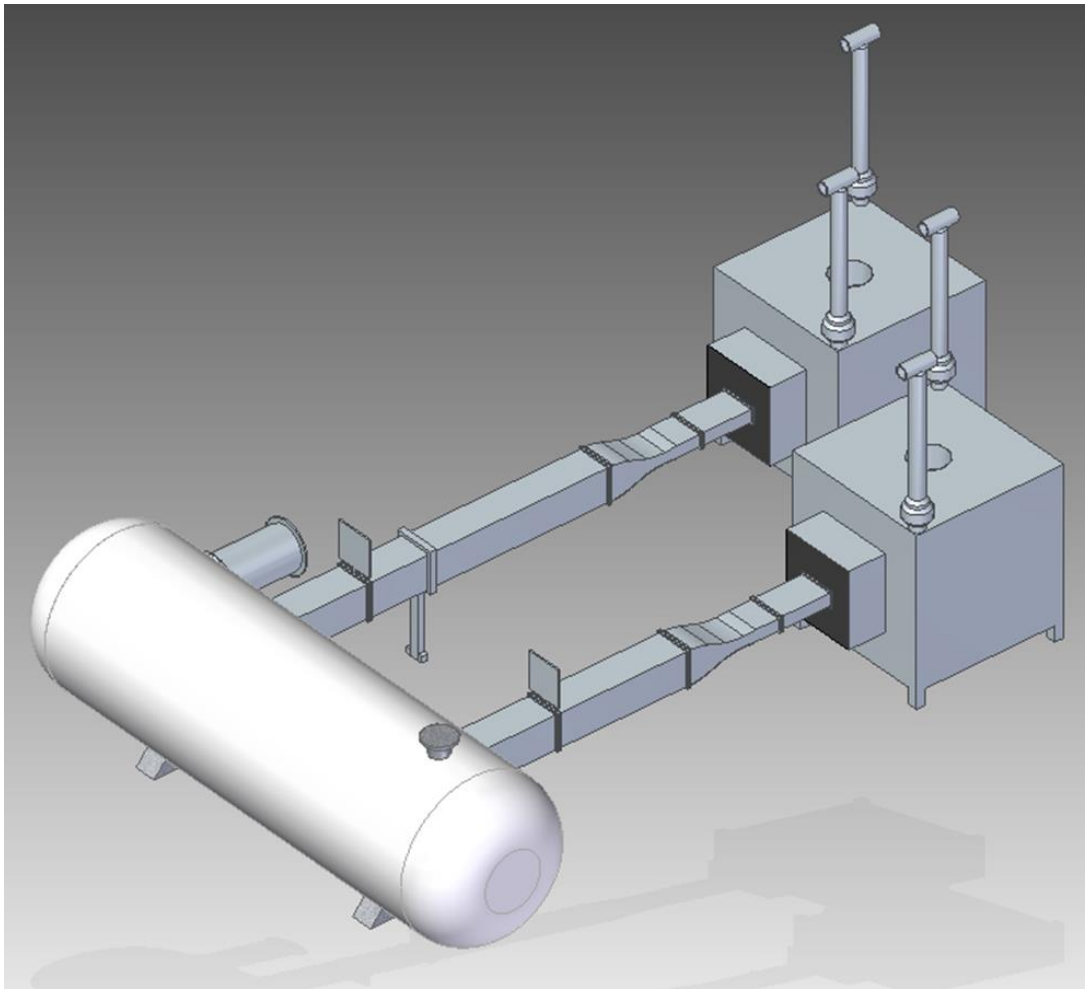


SuperSonic/TransSonic/WindTunnel

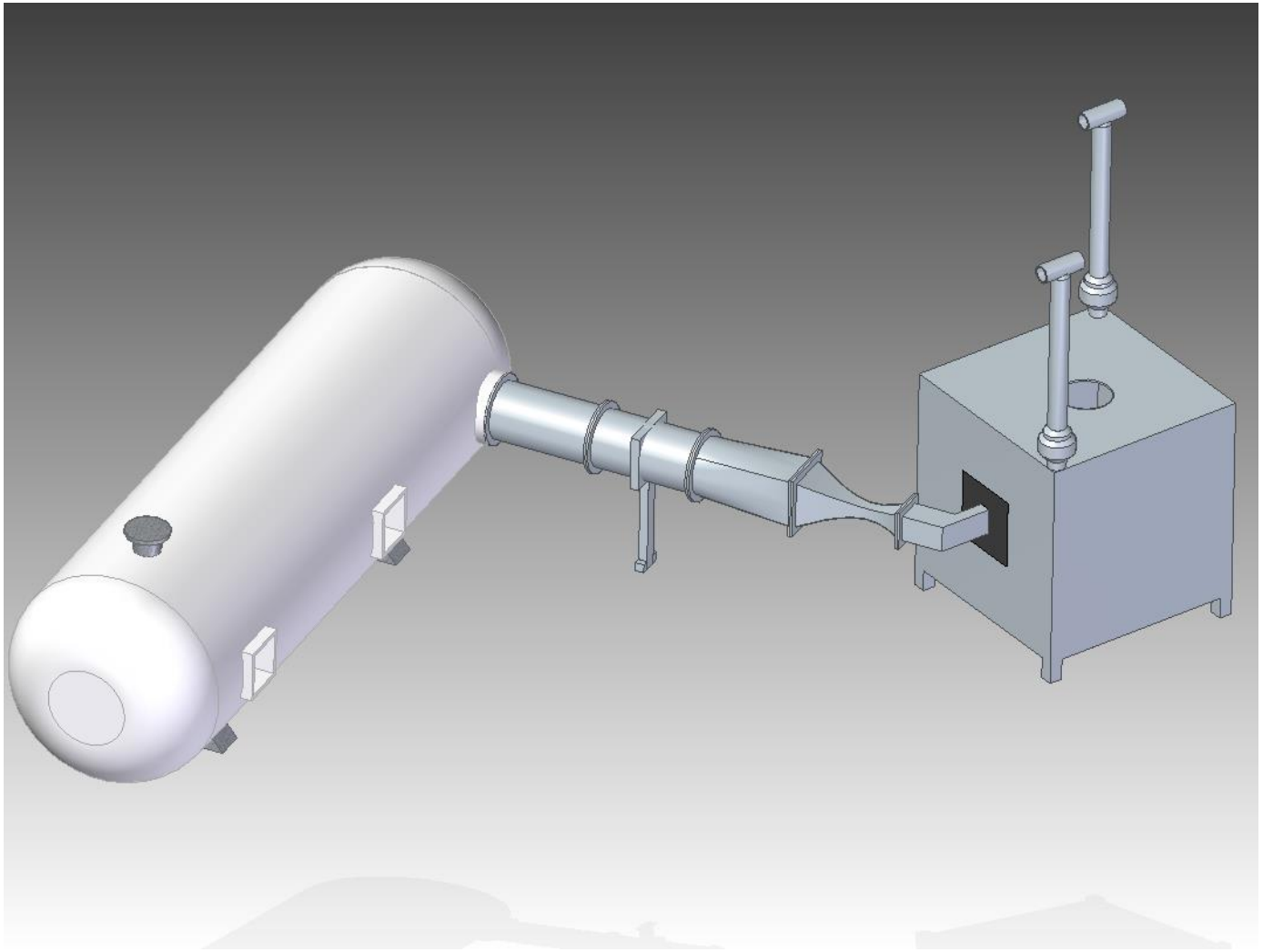
Air-Breathing Test Cell/ Test Sections



Test Sections

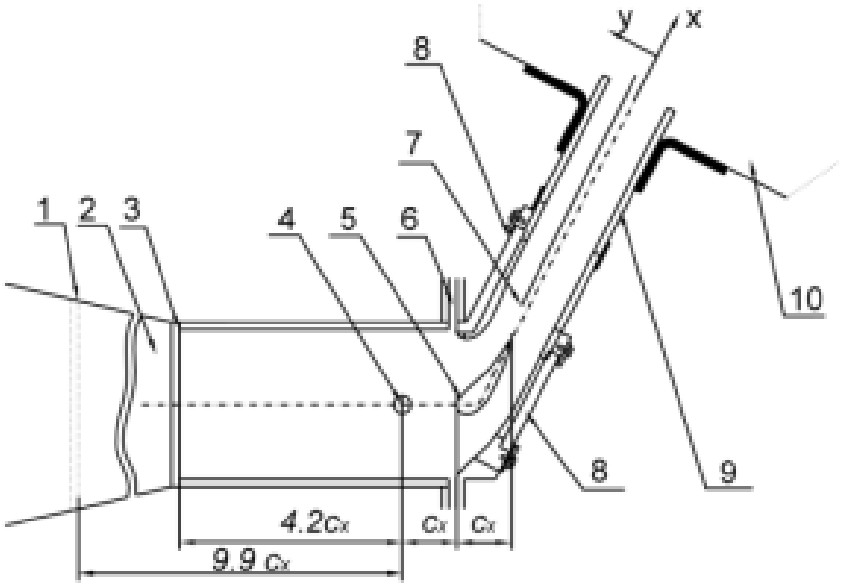


Test Section #3

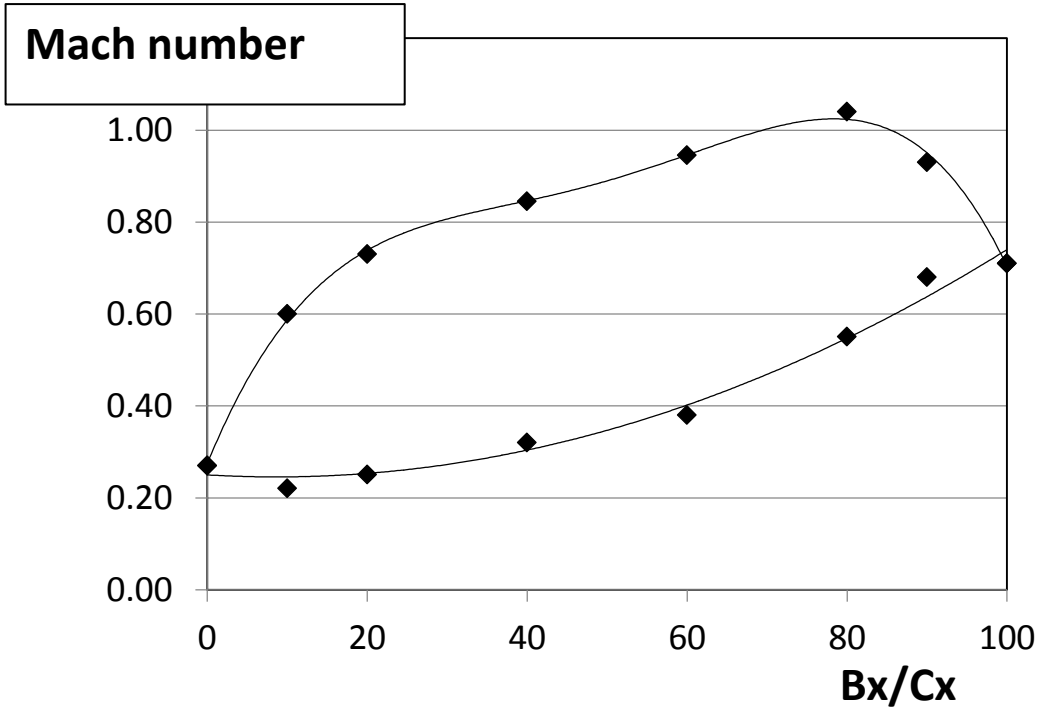


Test Section # 3

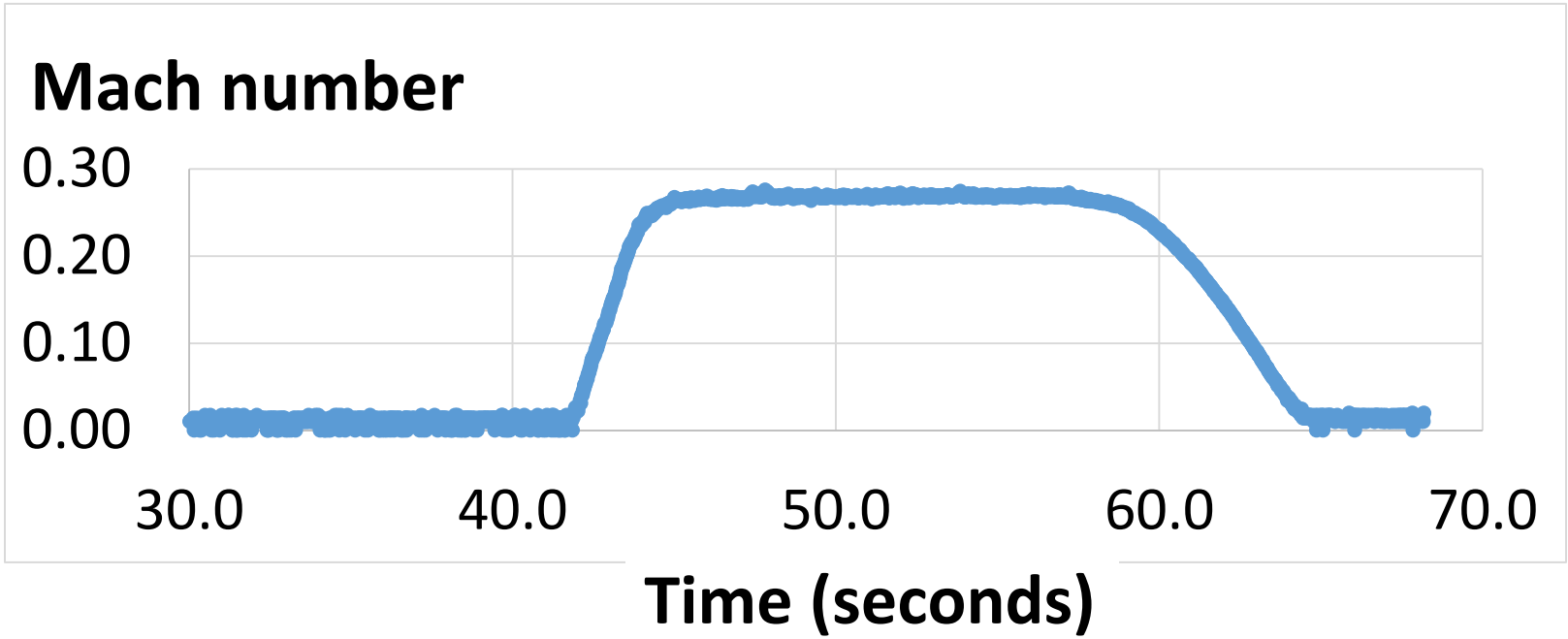
Schematic diagram of the test section, and Mach number distributions along the test cambered vane.



1. Bar Grid Position 2. Nozzle 3. Fine Mesh Grid Position
4. Inlet Pressure Probe and Thermocouple
5. Test Blade 6. Bleeding System
7. Exit Pressure Probe and Thermocouple
8. Zinc-Selenide Window 9. Tailboard 10. Exit Plenum

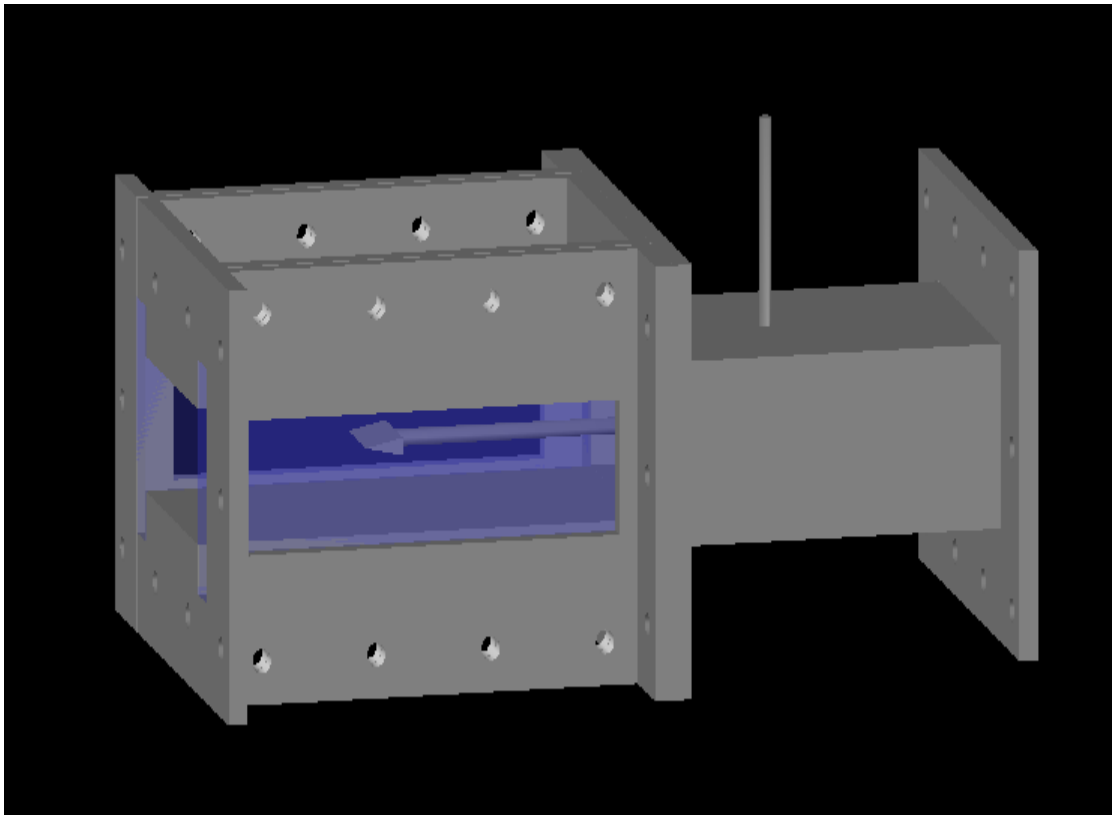


Mach number variation with time – turbine vane cascade inlet May 5, 2016.

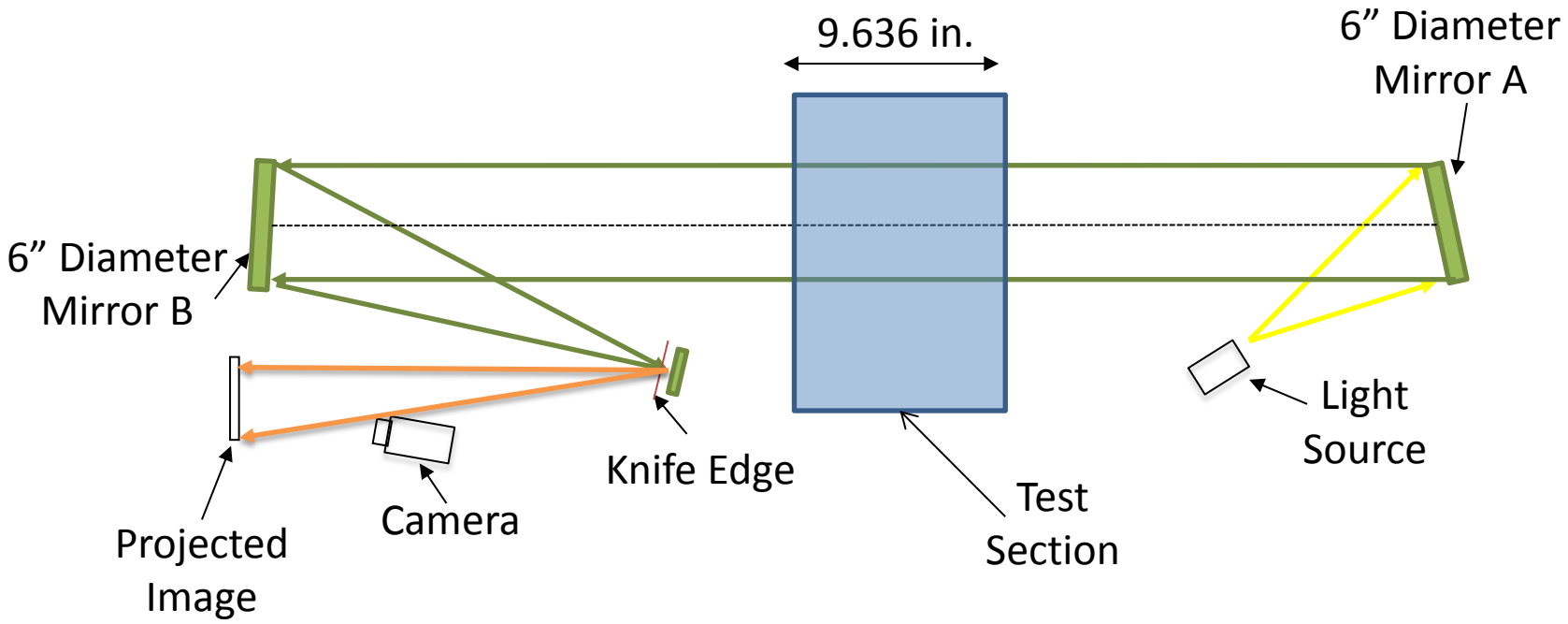


Class Instruction Test Section

- Test Section Inner Dimensions: 2.7 inches by 6 inches
- Wall Thickness: 0.5 inches
- Inner Surface Polished
- Corners: Sharp or very small radius
- Side Walls: clear acrylic or polycarbonate

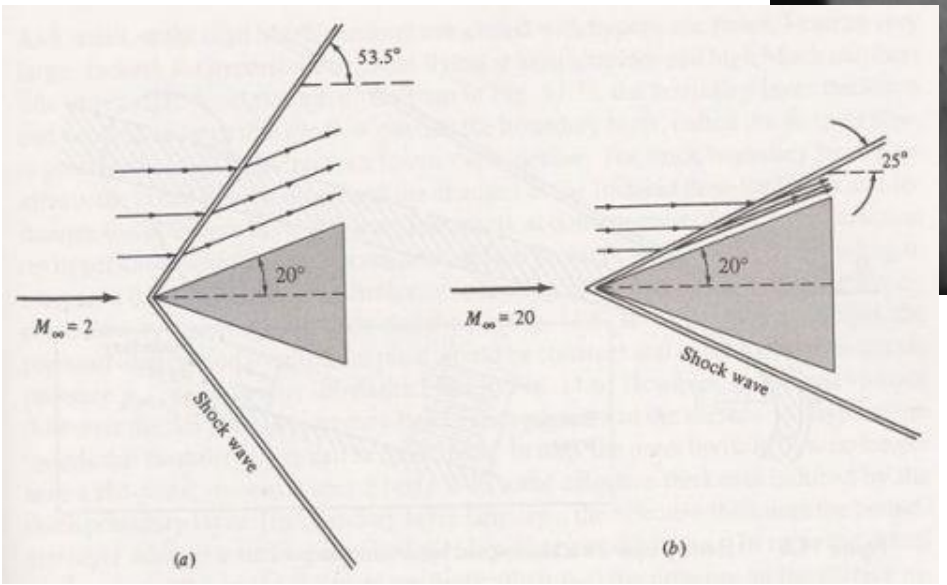


Instrumentation – Schlieren flow visualization system



Class Instruction Test Section

- Wedge shock wave instructional demonstrations



Research Test Section – SWBLI Investigations

Duct with bleed option

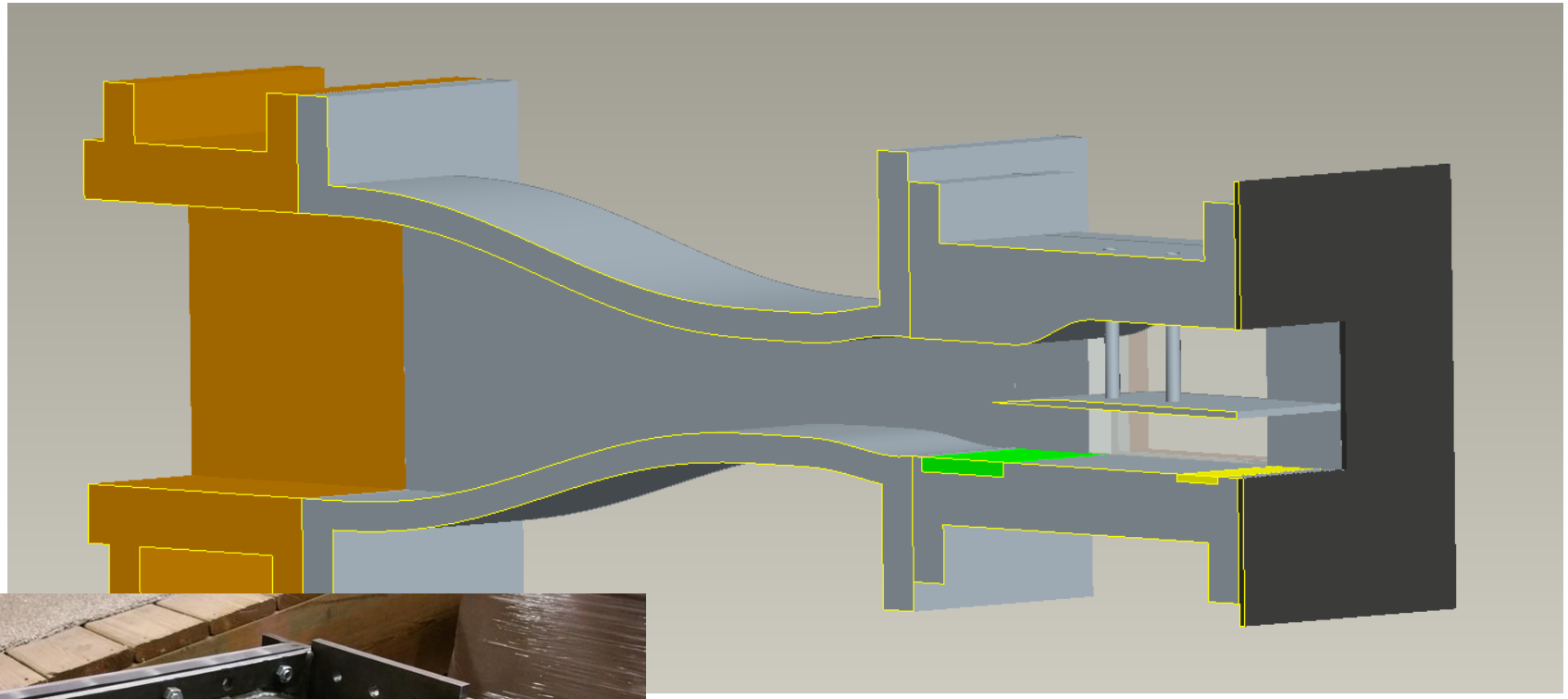
Optional bleed on every wall

2D nozzle

Large aspect ratio

Test section

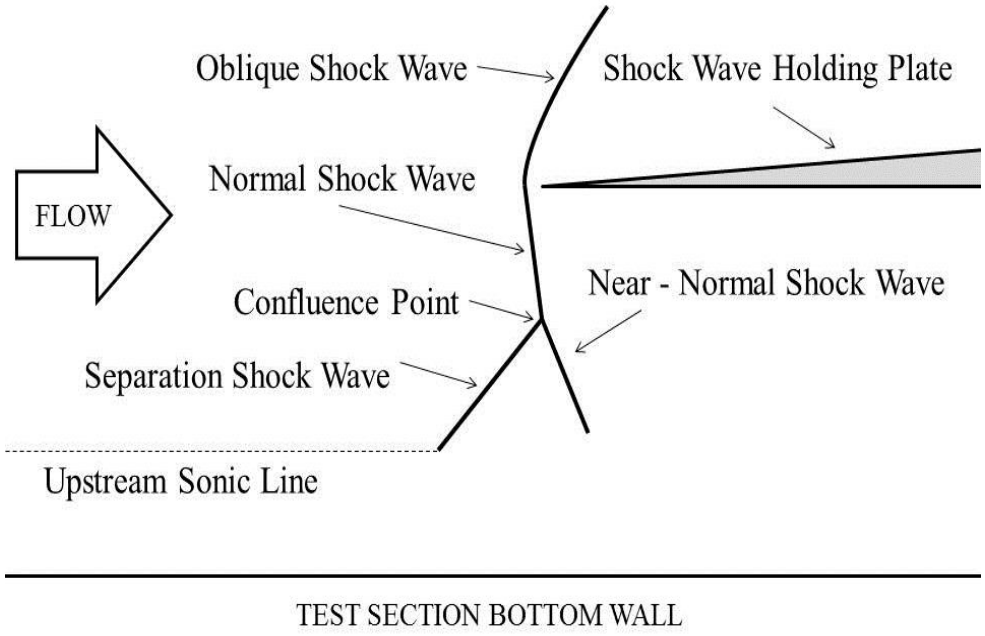
Large aspect ratio



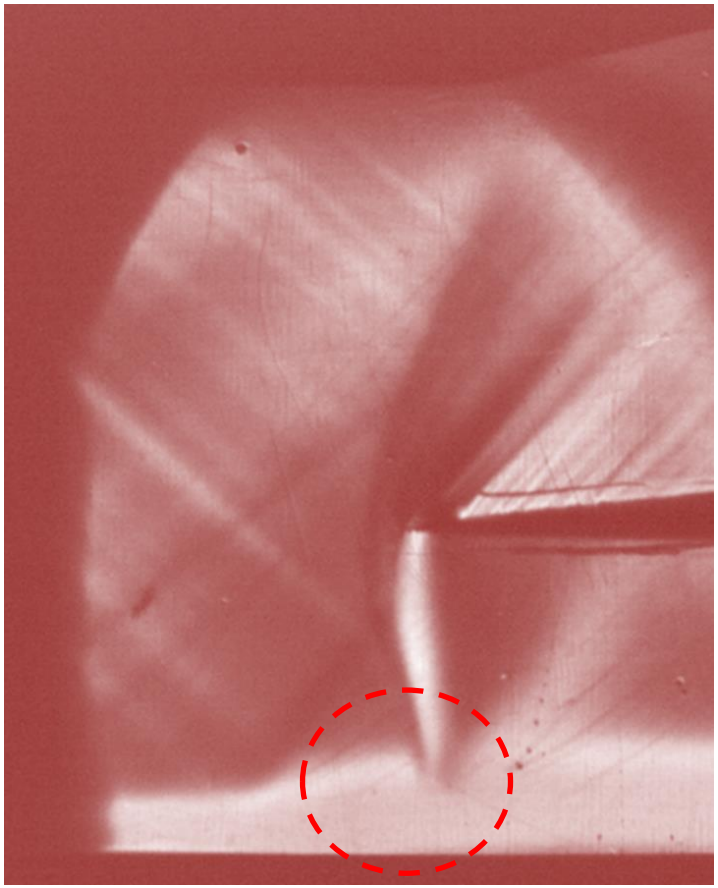
Centerline view of the test section.

SWBLI Result

- Adjust choking flap to choke bottom channel flow
- Modified oblique shock wave to normal shock wave



M_∞=1.62



SuperSonic/TransSonic/WindTunnel

Increased capabilities relative to many other facilities.

- UAH air storage capacity – 50 cubic meters.
- Pressure source capacity – 300 psi and 2500 psi.
- Test section mass flow rates up to 12-16 kg/sec.
- Test section inlet Mach numbers of 0.1 to 3.0.
- Test section inlet Mach numbers of 3.0 to 6.0.
- Capabilities to include *combustion* and *heat transfer*.
- Three different blow-down test operating modes with both High Pressure (2500 psi) and Intermediate Pressure (300 psi) Air Storage….*flexible capabilities*…..

SuperSonic/TransSonic/WindTunnel

LAB CAPABILITIES

Personnel – UAH Propulsion Research Center

- PHIL LIGRANI – Experimental supersonic flow researcher
- KADER FRENDI – Numerical supersonic flow researcher

- BOB FREDERICK – Propulsion Research Center - Director
- TONY HALL – Full-time Laboratory Engineer
- DAVID LINEBERRY - Full-time Laboratory Manager and Laboratory Safety Officer

- Excellent students and faculty colleagues
- Existing and well established ITAR, EXPORT CONTROL, and PROPRIETARY RESEARCH practices, capabilities, and facilities

- RAY VAUGHN – Vice President for Research – excellent SRO - Sponsored Research Office

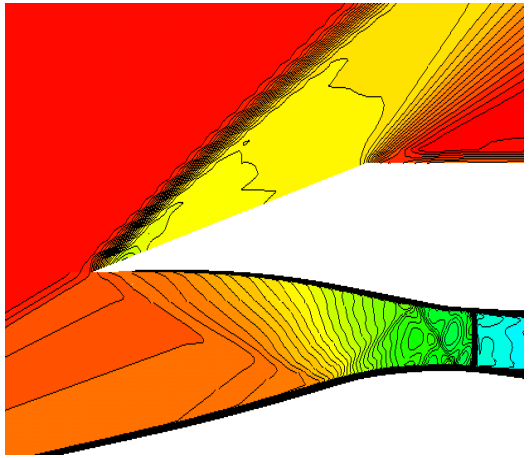
SuperSonic/TransSonic/WindTunnel

LAB CAPABILITIES

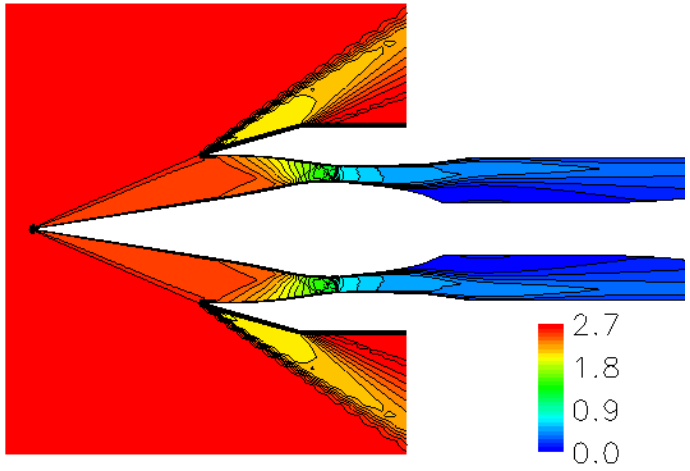
Measurement Capabilities, Probes, Instrumentation

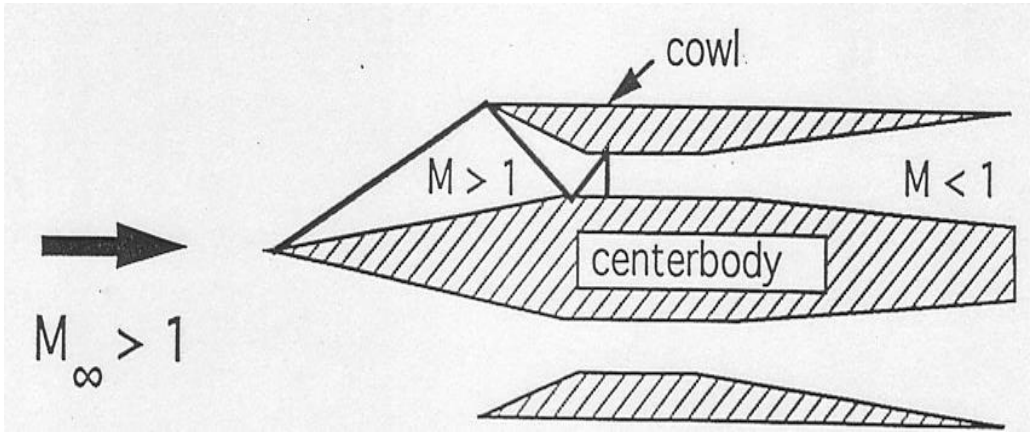
- Schlieren flow visualization system
- PIV – Particle Image Visualization – system
- Pressure instrumentation – Validyne pressure transducers, diaphragms, and carrier demodulators, including high pressure transducer calibration system
- Stagnation pressure probes, surface static pressure tappings
- Temperature instrumentation – Omega thermocouples and measurement system, including thermocouple calibration bath and resistance thermometer as temperature standard
- Computers and DAS – Data Acquisition System – including National Instruments data acquisition / multiplexer (analog-to-digital conversion) cards
- Surface oil flow visualization capability
- CCD cameras for time-resolved data
- FLIR infrared camera with 60 hertz time-resolved acquisition capability

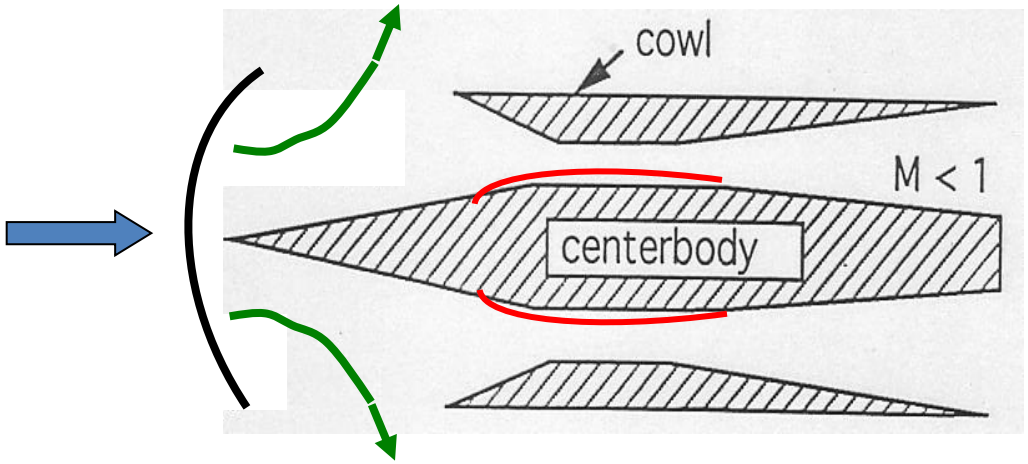
APPLICATIONS - What happens when a shock wave strikes a boundary layer?



Consequences of shock-induced separation?



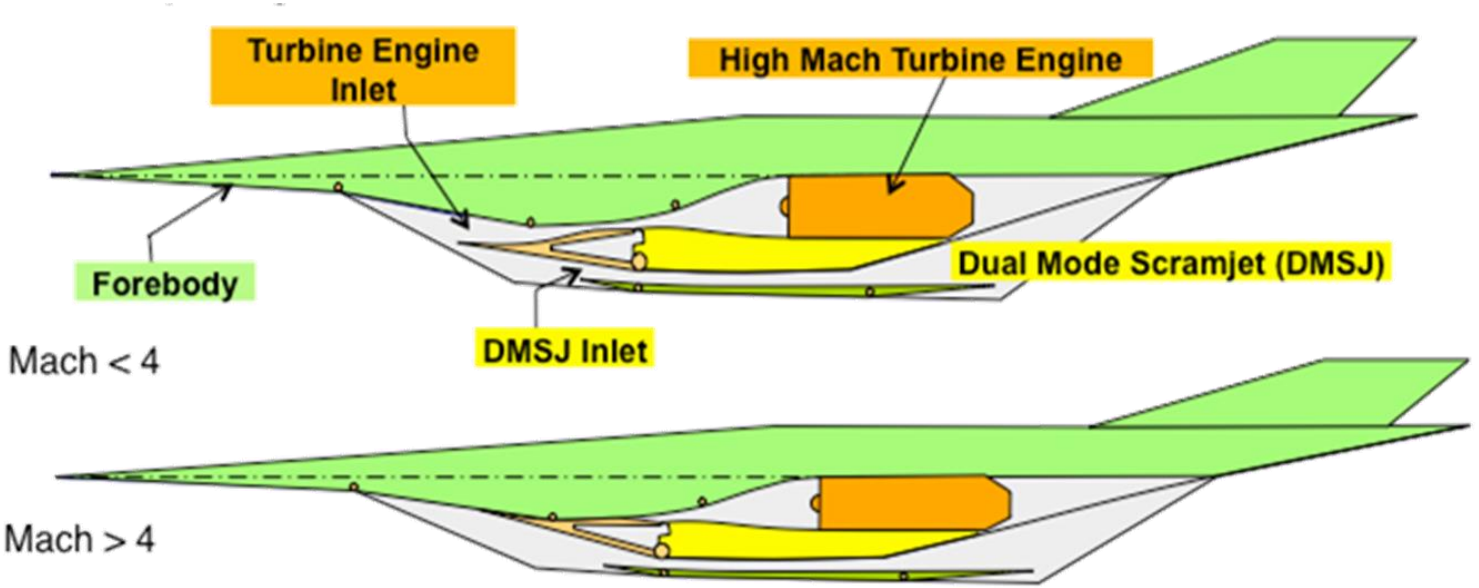




Flow separation changes effective geometry.

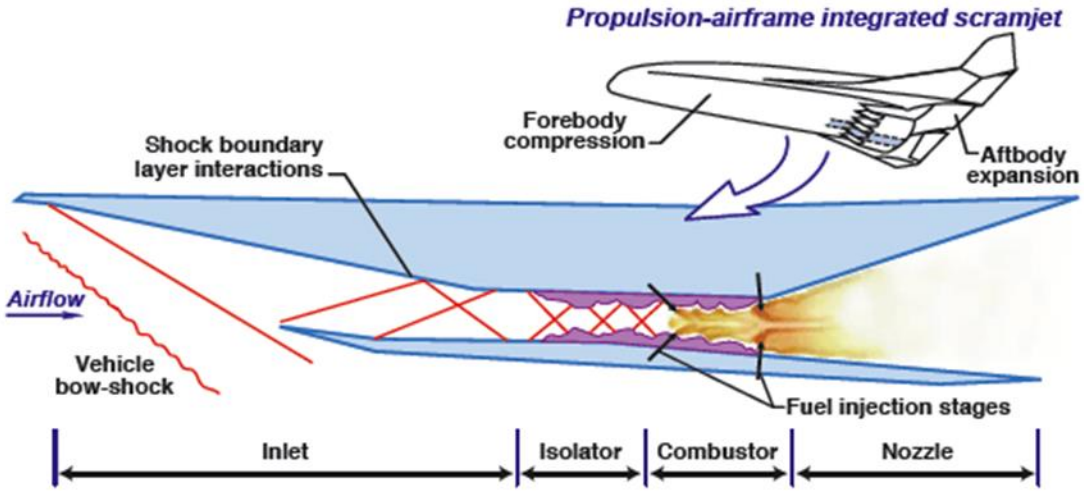
Shock pops out & **engine “unstarts”!**

APPLICATIONS



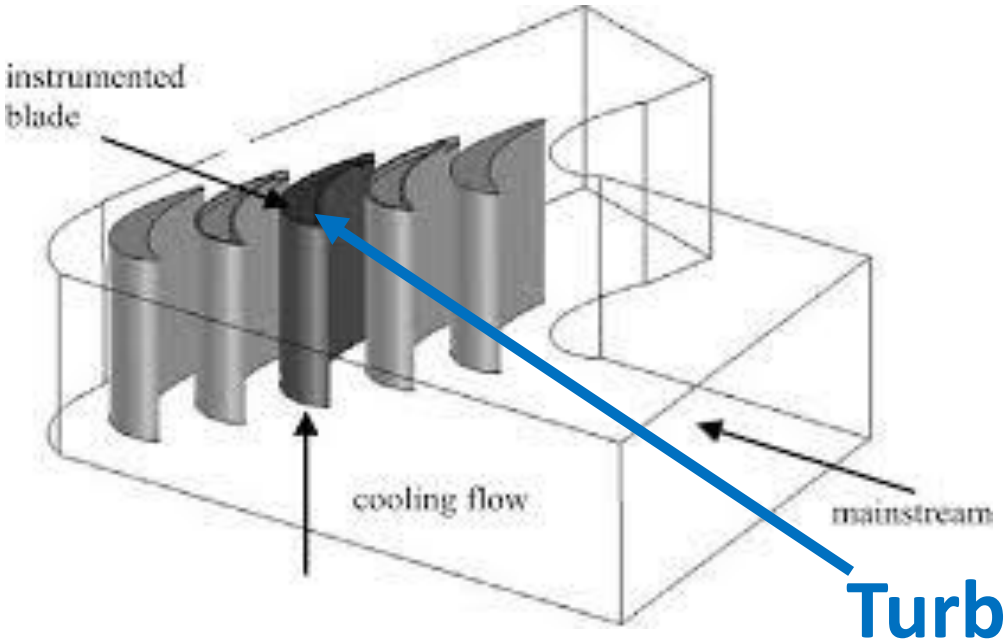
- Hybrid space vehicle

- Scramjets

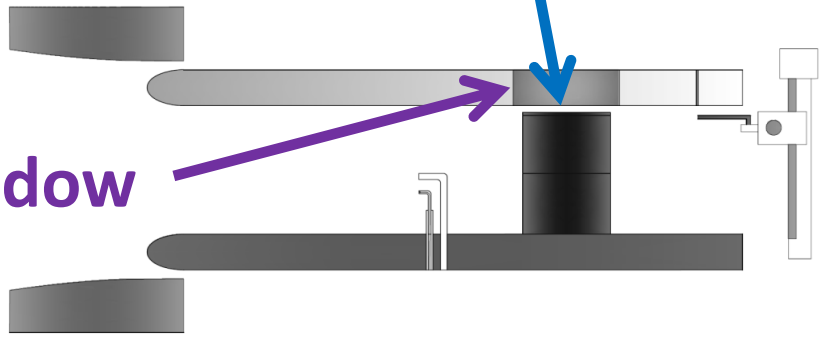


APPLICATIONS……

Transonic Turbomachinery CASCADES



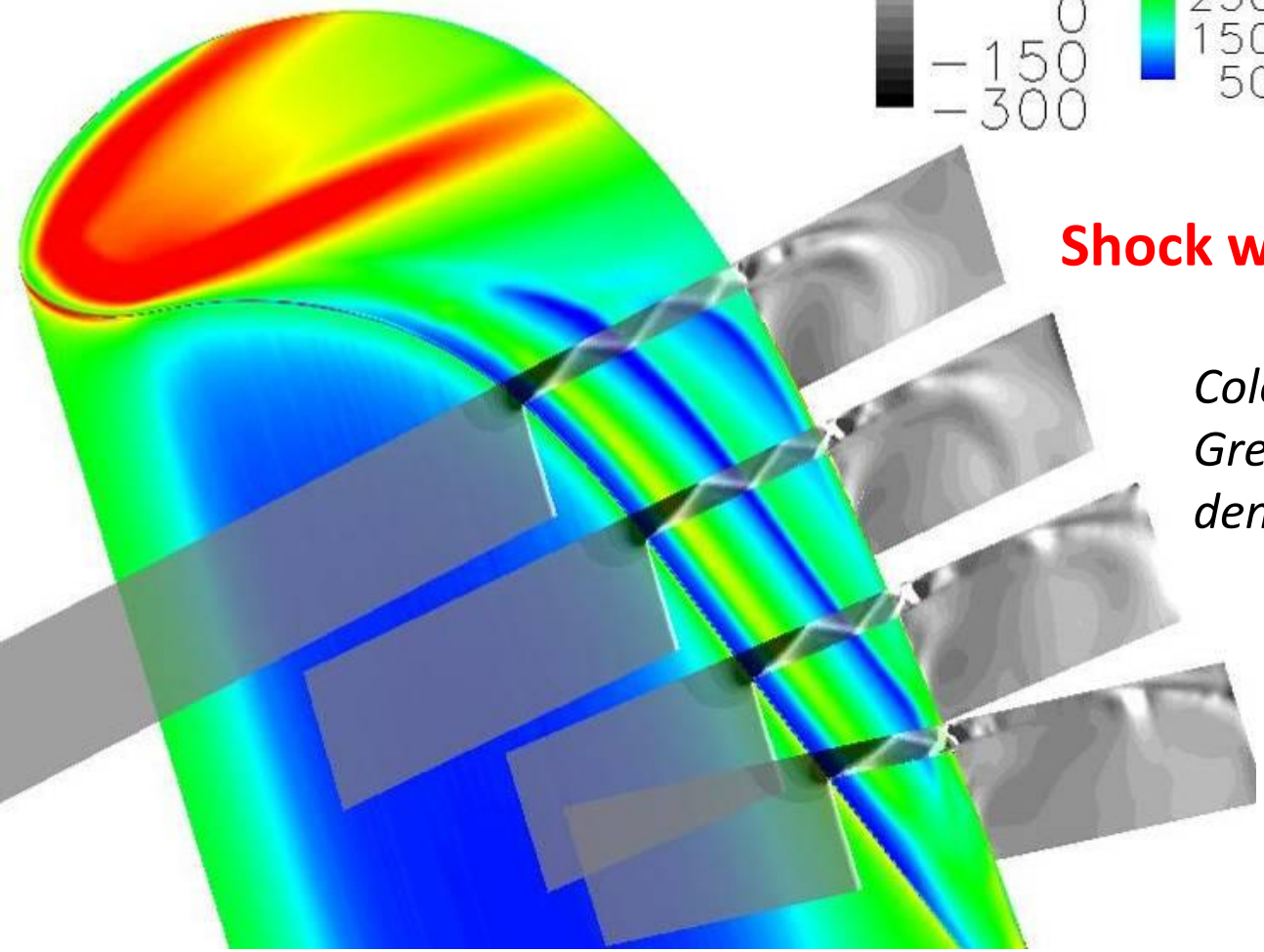
Turbine blade tip



Optical access window

SHOCK WAVE EFFECTS: A virtual Schlieren visualization

Flat tip, 1.5% tip gap



Shock wave signatures !

Color: Tip surface heat flux
Greyscale: x-components of density gradient distributions

$2 MILLION - FACILITY

SS/TS/WT

SuperSonic/TransSonic/WindTunnel

SuperSonic/TransSonic/WindTunnel

SS/TS/WT

THANK YOU:

Alabama Innovation Fund

UAH – Office of the VPRED

UAH – Other sources of funding

AEDC – Arnold Engineering Development Center – Arnold Air Force Base – Mr. Elmer Standridge

UAH PRC MAE **SS/TS/WT** Facility

SuperSonic/TransSonic/WindTunnel

University of Alabama in Huntsville

THE END